Australian/NSW coastal sediment compartments: concept and application

AD Short, BG Thom
School of Geosciences
University of Sydney NSW 2006

Abstract

The Australian Coastal Sediment Compartment Project (ACSCP) was initiated in 2012 by BGT with the assistance of Geoscience Australia, transferring to the National Climate Change Research Adaption Facility (NCCRAF) in 2014. Thom and a team of six coastal experts mapped a hierarchy of compartments around the entire Australian coast. This paper briefly reviews this hierarchy and its application in NSW. It then considers their now mandatory application in NSW coastal management, the process of examining a sediment compartment, and provides an example of sediment behaviour in one NSW south coast compartment.

Introduction

The concept of sediment compartments was first developed in southern California by Inman and Chamberlain (1960). In Australia Davies (1974) developed a conceptual model applicable to the Australian coast and Davies and Hudson (1987) applied this to an investigation of sediment sources and transport along the north coast of Tasmania. The concept was first incorporated into beach management in the USA by Komar (1976), and in the UK by Cooper et al. (2002, 2006). In Australia the first mapping of east coast sediment compartment boundaries was made by Chapman et al. (1982) for the entire NSW coast. More recently in WA Stul et al. (2007) and Eliot et al. (2011) divided the entire WA coast into primary, secondary and tertiary compartments (PC, SC and TC) and applied these to assessing coastal vulnerability for use in coastal planning and management. Recognising the need to expand this approach nationally the ACSCP was initiated by Thom in 2012 with the assistance of Geoscience Australia, transferring to the NCCRAF in 2014. Thom and a team of six coastal experts identified two coastal provinces, seven divisions, 23 regions, 102 primary compartments (PC) and 354 secondary compartments (SC) that covered the entire Australian coast (http://coastadapt.com.au/coastadapt-interactive-map; Thom et al. 2018) which incorporated the already defined WA compartments. This paper uses this framework to discuss the nature of the Australian coast and its sediment compartments and in particular its now mandatory application in NSW.

Australian sediment compartments: province to tertiary

A *sediment compartment* is a section of coast which shares a common sediment resource with clearly defined physical boundaries. The compartment may be open, leaky or closed at either or both boundaries and the sediment budget may be positive, stable or negative. Table 1 lists the provinces, divisions, regions and number of primary and secondary compartments around the Australian coast, which are also mapped in Fig. 1. The boundaries for each level are defined using the following criteria: The two *provinces* are based solely on climate and divided roughly along the Tropic of Capricorn (between North West Cape 21°45'S and Sandy Cape 24°40'S) into the northern tropical coastal province and southern temperate coastal province; the seven *divisions* are based on province, then primarily coastal orientation (NW, NE, SE, S and SW), apart from the Gulf of Carpentaria; the *regions* are based on division, then geology, with some contribution from coastal orientation/configuration, as in Tasmania and South Australian gulfs; the 102 *primary compartments (PC)* are based on regions, which are then subdivided at major physical coastal boundaries into compartments which are sections of the coast that are bounded by major, usually distinctive, structural features such as rocky headlands or major changes in orientation of the coast; the 354 *secondary compartments (SC)* are based on primary compartments, with subdivisions into SC's at prominent secondary coastal boundaries; and the as yet unknown number of *tertiary compartments (TC)* are based on secondary compartments, which are sub-divided at obstructions (usually headlands) into TC's, some as small as an individual beach, most of which are closed sediment cells. Each region, PC and SC ic codified by State, region, PC number and SC number providing a unique identifier for all 354 SC's. All NSW regions, PC's and SC's are listed in Appendix 1. For a description and lists of all Australian provinces, divisions, regions and PC's and SC's see Short (in press).

Table 1 The division of the Australian coast into provinces, divisions and regions based on the Australian Coastal Sediment Compartments Project (source: Short in press).

Province	No.	Division	No.	Region	Primary	Secondary
Tropical	1	Northwest	1	Pilbara	8	23
	2	Kimberley-NT	3	Kimberley	5	14
			3	Western NT	2	10
			4	North Arnhem Land	4	10
	3	Gulf Carpentaria	5	East Arnhem	2	7
			6	Southern Gulf	2	4
			7	W Cape York Pen	2	3
	4	Northeast	8	E Cape York Pen	8	34
			9	Central Qld	4	21
Temperate	5	Southeast	10	Central eastern	6	22
			11	Southern NSW	6	34
			12	Gippsland	3	5
			13	Eastern Tasmania	6	17
	6	Great Southern	14	Western Tasmania	3	13
			15	Northern Tasmania	4	8
			16	Central & West Vic	3	17
			17	Southeast SA	4	8
			18	SA Gulfs	2	13
			19	Western Eyre Pen.	4	11
			20	Nullabor	3	9
			21	Southeast WA	7	26
	7	Southwest	22	Southwest WA	7	21
			23	Central West WA	7	24
2	7		23		102	354

The compartment boundaries may be *fixed* (e.g. headland, rocky point) or *ambulatory* (e.g. a sandy foreland) and may be completely *closed* to sediment transport, *leaky* with occasional or episodic transport, or *open* with ongoing transport across the boundary.

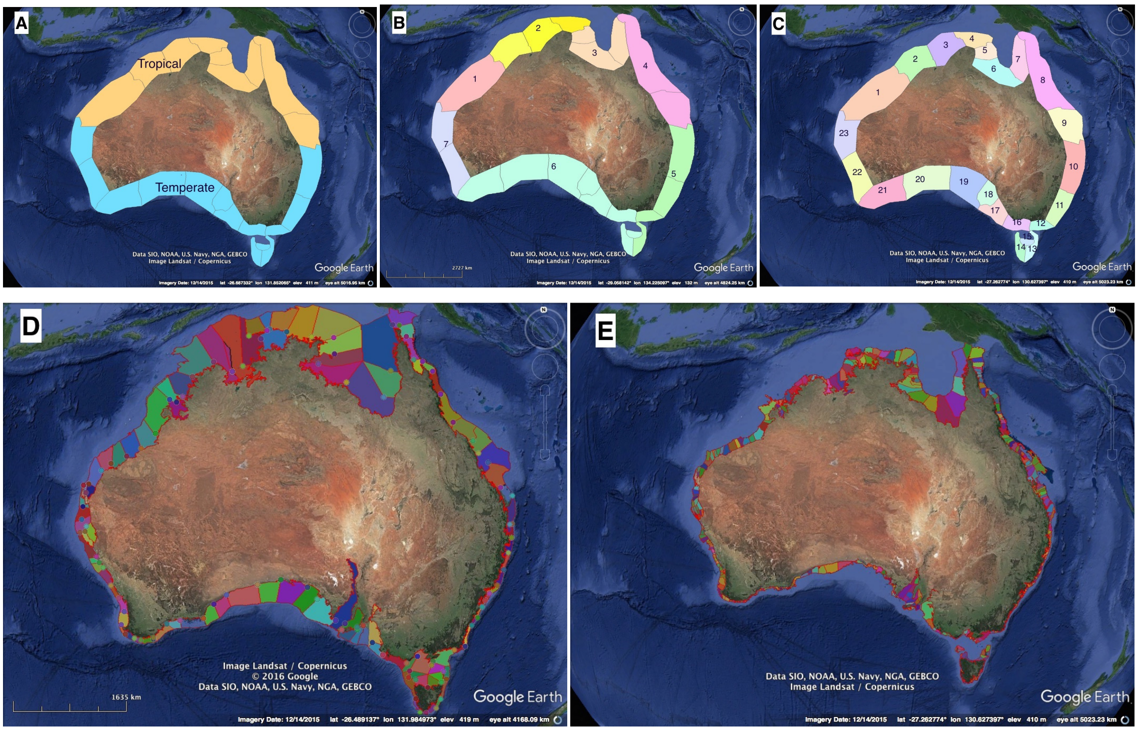

Figure 1: Australian coastal sediment compartments: a) two provinces; b) seven divisions; c) 23 regions; d) 102 primary compartments; and e) 354 secondary compartments (from Short, in press)

The tropical northern province (Fig. 1a) is typified by its tropical climate, seasonal monsoonal rainfall, low to moderate seas, meso to mega-tides, exposure to tropical cyclones and numerous rivers and streams delivering terrigenous sediment to the coast, much of which is deposited locally. Sediments range from carbonate-rich in the west, to quartz-rich in the east and mixed across the north. Longshore transport is driven by the trade wind waves and is predominately northerly reaching maximum rates of several 10 000 $m^3\ yr^{-1}$. It is however continually interrupted by both bedrock and reef obstacles and the numerous tidal creeks and rivers. In contrast the temperate southern province is exposed to low through high waves, predominately micro-tides, with fewer rivers most of which are supplying bedload sediment to estuaries, but not the coast. Longshore sand transport has been and is substantial along the east and west coasts, reaching 500 000 $m^3\ yr^{-1}$ at the Tweed and up to 100 000 $m^3\ yr^{-1}$ on parts of the southwest WA coast, with massive onshore transport across the southern coast. The culmination of this transport has been the deposition of thousands of beaches, barriers including massive dune systems, flood tide deltas and in the south, shelf sand bodies. Today however subtle variation in the transport within and between compartments affects their sediment budget which can lead to contemporary shoreline accretion, stability or recession. Likewise, predicted changes in climate, sea level, wave climates, tides and winds will impact future transport, budgets and shoreline behaviour. The sediment compartment approach provides a framework within which to study sections of coast linked by a shared sediment budget, whose present and future behaviour will determine the shoreline stability and coastal vulnerability, both essential for effective coastal planning and management.

NSW coastal compartments

The NSW coast is located in the *southern province* and the *southeast division* which has boundaries at Sandy Cape on Fraser Island and Tasmania's South East Cape (Fig 1a, b). It is then subdivided between two regions (10 and 11, Fig 1.1c), the *central east* (Sandy Cape to Cape Hawke) which it shares with SE QLD, characterised by generally longer embayed beaches, headland bypassing and a near continuous longshore transport of fine quartz sand terminating at Fraser Island; and *southern NSW* (Cape Hawke to Cape Howe) characterised by shorter more deeply embayed beaches, numerous estuaries and interrupted and very limited longshore transport of fine through medium and some carbonate-rich sediment. In NSW the two regions contain nine PC's (Fig. 2) and 46 SC's (Fig. 3; Appendix 1), which Kinsela et al. (2017) divide into 137 TC's.

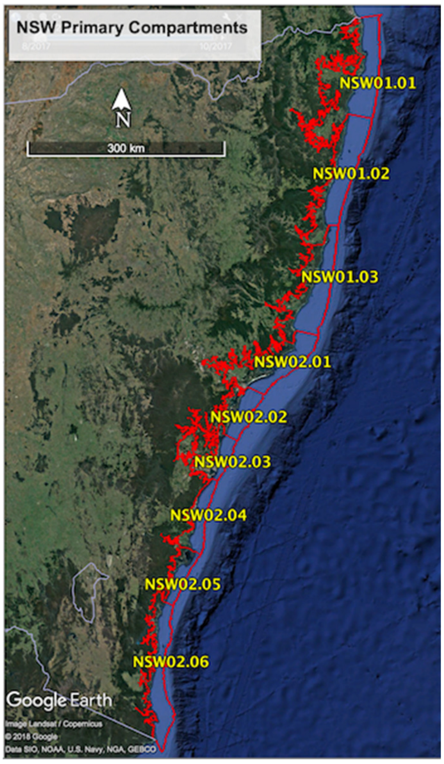

Figure 2: NSW nine primary sediment compartments (source: Google Earth)

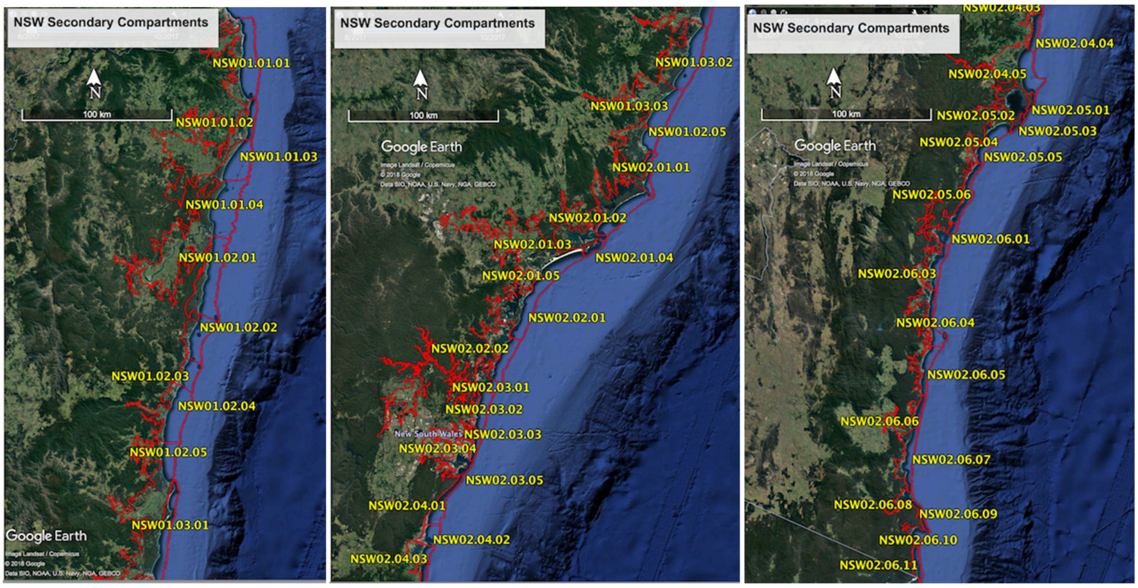

Figure 3: NSW 46 secondary sediment compartments (source: Google Earth)

The SC's are recognised in the new NSW Coastal Management Manual (NSW 2016) which recommended their use as a basis for understanding coastal processes and hazards in the development of coastal management programs. Within this framework the manual states: "that studies in coastal vulnerability areas should consider the following":

- the **geological and geomorphic** structure and evolution of the coast;
- quantification of local and regional and **coastal and ocean processes** at relevant spatial and temporal scale down to the TC level;
- **sediment sharing** between PC, SC and TC's on the open coast and with estuaries;
- develop conceptual model of **sediment budgets**;
- **human modification** of the coast;
- the potential effects of **climate change** including shoreline rotation, sea level rise, changes in storm type, frequency and intensity;
- the impact of **ENSO** cycles & other climate cycles such as the Interdecadal Pacific Oscillation (IPO);
- the degree of **uncertainty** in the above factors;
- consult with **adjoining councils** where compartments are shared when preparing a detailed coastal hazard assessment.

The sediment compartment approach provides the framework for encapsulating all the above as it covers a section of coast, irrespective of LGA boundaries that share common processes, geology and geomorphology, and in particular a common sediment source which may be linked to adjoining compartments via leaky or open boundaries. The compartment will also be exposed to the same climate cycles and impacts of climate change. Thom et al. (2018) provides a number of case studies of sediment compartments from contrasting environments from around Australia, while Eliot et al. (2011) and Stul et al. (2007; 2014a, b; 2015) apply the approach to assessing coastal vulnerability along long sections of the WA coast.

In NSW while the above dot points list what is required in a vulnerability study it does not detail the process and technology available to undertake such a study. A compartment study should commence with detailed mapping of the entire compartment using Lidar and/or swath mapping to identify the bathymetry of the seabed particularly the nature and extent of sediment and bedrock (Kinsela 2018), and the role of the latter in impeding sediment transport. This should be followed by seabed sampling to determine the sediment characteristics and if possible sub-bottom profiling to assess the thickness of sediment, thereby mapping the area and volume of sediment, together with its characteristics, within the compartment. Next is an understanding of the prevailing processes; waves, tides, wind, ocean currents and extreme events, all of which will play a role in sediment mobilisation and transport. At the same time the history of decadal scale beach change can be obtain from photogrammetry, satellite imagery and where available repetitive surveys, even using satellites (Vos, 2018). These will enable an assessment of the controls on beach change including response to extreme events and climate indices such as ENSO, as well as assessing storm demand, the degree of oscillation and rotation and their causes, and the direction of beach change (stable, accreting, receding). Finally, a range of models can be used based on the boundary conditions to predict onshore and longshore sediment transport and shoreline response to contemporary, extreme and future events. Woodroffe et al. (2012) review the range of approaches to assessing coastal risk on the Australian coast, while Kinsela et al. (2017) presents a 'simple shoreline encroachment model' which uses the sediment compartment approach for predicting beach recession on the NSW coast, and Kinsela (2018) compares two adjacent but contrasting NSW SC's.

Fig. 4 illustrates one south coast SC (NSW02.06.03) containing a series of open to leaky TC's which extends for 43 km from Bingie Bingie Point to Mosquito Bay point, where studies have been conducted on seabed mapping, the Quaternary history of its barrier systems (Oliver et al. 2015, 2018), repetitive beach surveys (Mc Lean et al. 2010, 2018; Short et al. 2014) and the nature of a northern leaky boundary (Coglhan et al. 2018). The results suggest that quartz-rich sand has been delivered to the TC's filling the compartments between Bingie Bingie Point and Moruya Heads. Oliver et al. (2018) found that the Pedro TC received an abundance of quartz-rich sand (1575 m^3 yr^{-1}) accompanying and subsequent to the Holocene marine transgression, sufficient sand to prograde and fill the TC by 3.9 ka, following which the excess sand moved northwards around Pedro Point into the Moruya TC and probably from there around Moruya Heads into the Bengello TC which still appears to be in filling (Oliver et al. 2015). Quartz-rich sand from Bengello however periodically leaks via the Broulee Island tombolo into the Broulee TC, diluting the carbonate-rich sand north of Broulee Island, while the northern end of the Broulee-Barlings TC is closed at Burrewerra Point. It therefore appears that while the beaches oscillate and rotate up to 100 m in response to east coast cyclones and ENSO, they appear to have stable shorelines with sand continuing to move onshore at unknown rates into the SC and longshore leaking between the TC's to maintain stable shorelines in the south (Pedro and Moruya, Short et al. 2014) and an accreting shoreline at Bengello (McLean et al. 2010, 2018) and Broulee (Coghlan et al. 2017). While more work is required to identify and quantify the sand sources and transport rates, existing studies provide an insight into the Holocene evolution of this SC, its receipt and distribution of shelf derived sediment and the contemporary linkages between the TC's and their shoreline behaviour.

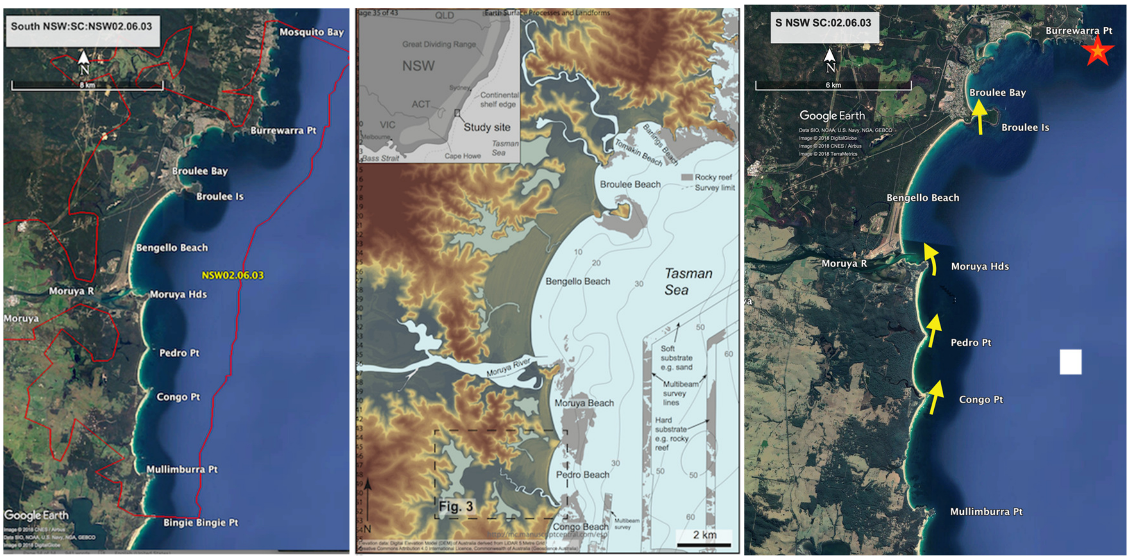

Figure 4: Southern NSW SC:NSW02.06.03 (Mosquito Bay-Bingie Bingie Point); b) Broulee to Pedro barrier systems and Moruya river mouth (Oliver et al. 2018); and c) conceptual model of longshore sand transport. Red star indicates closed boundary.

Summary

The study of coastal systems based on their sediment compartment and budget was initiated in the 1960's and more recently has been used as an approach to better understand coastal behaviour for application in coastal management. The ACSCP was initiated in 2012 and released online in 2017 (http://coastadapt.com.au/coastadapt-interactive-map) and published in Thom et al. (2018) and Short (in press). This project mapped all 354 Australian SC's. In NSW there are nine PC's, 46 SC's AND 137 TC'S, with the SC's listed in the new NSW Coastal Management Manual detailing how they are to be studied so as to improve our understanding of coastal behaviour at an SC and

TC level and better inform coastal management. At the core of the SC approach is the need to understand the role of geology, coastal processes and sediment sources and transport within and through the compartment/s, irrespective of LGA boundaries, and how they impact shoreline behaviour now and into the future. It is in effect examining the entire regional coastal system and its interactions, rather than just the beach or estuary or a section of coast. In investigating how the entire system operates and the way sediment moves through the system and the impacts this movement has, it will enable the causes of shoreline change to be identified. This will enable managers to, where possible rectify the causes of adverse changes or where not possible to work with and prepare for future changes.

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Appendix 1: NSW regions, PC's and SC's

Region/PC/SC No.	Boundaries	NSW Beach ID[1]	No. beaches	NSW km[1]	Length (km)
Central east region					
NSW01.01.01	Pt Danger-C. Byron	1-15	15	0-61	61
NSW01.01.02	C. Byron-Richmond R	16-28	13	61-92	31
NSW01.01.03	Richmond R-Evans Hd	29-30	2	92-123	31
NSW 01.01.04	Evans Hd-Yamba	31-43	13	123-167	44
PC:NSW01.01	*Pt Danger-Richmond R*	*NSW 1-43*	*43*	*0-167*	*167*
NSW 01.02.01	Yamba-Barcoongere	44-74	31	167-228	61
NSW01.02.02	Barcoongere-Bare Bluff	75-93	19	228-263	35
NSW01.02.03	Bare Bluff-Coffs Harbor	94-112	19	263-290	27
NSW01.02.04	Coffs Hbr-Nambucca Hd	113-127	15	290-333	43
NSW01.02.05	Nambucca Hd-SW Rocks	128-137	10	333-368	35
PC:NSW01.02	*Richmond R-SW Rocks*	*NSW 44-137*	*94*	*167-368*	*201*
NSW01.01	SW Rocks-Tacking Pt	138-170	33	368-450	82
NSW01.03.02	Tacking Pt-Crowdy Hd	171-184	14	450-508	58
NSW01.03.03	Crowdy Hd-Black Hd	185-192	8	508-540	32
NSW01.03.04	Black Hd-C Hawke	193-200	8	540-560	20
PC:NSW01.03	*SW Rocks-C. Hawke*	*NSW-138-200*	*63*	*368-560*	*192*
	Region total		*200*	*0-560*	*560*
South NSW region					
NSW02.01.01	C Hawke-Seal Rocks	201-217	17	560-594	34
NSW02.01.02	Seal Rocks-Yaccabba	218-223	6	594-648	54
NSW02.01.03	Yaccabba-Zenith Pt	PS 1-15	15	PS 0-25	25
NSW02.01.04	Zenith Pt-Birubu Pt	224-237	14	648-671	23
NSW02.01.05	Birubi Pt-Nobbys Hd	238-240	3	671-704	33
PC:NSW02.01	*C. Hawke-Hunter River*	*NSW 201-240*	*55*	*560-704*	*169*
NSW02.02.01	Nobbys Hd-Norah Hd	241-272	32	704-762	58
NSW02.02.02	Norah Hd-C Three Pts	273-289	27	762-800	38
PC:NSW02.02	*Hunter R-C Three Pts*	*NSW 241-289*	*49*	*704-800*	*96*
NSW02.03.01	C Three Pts-Barrenjoey	290-299	10	800-838	38
	Middle Hd-Barrenjoey	Broken Bay 1-21	21	BB 39	39
NSW02.03.02	Barrenjoey-North Hd	300-319	20	838-876	38
NSW02.03.03	North Hd-South Sd	Sydney Hbr 1-52	52	SH 64	64
NSW02.03.04	South Hd-C Banks	320-330	11	876-905	29
NSW02.03.05	C Banks-Hacking Pt	331-340	10	905-926	21
	C BanksSutherland Pt	Botany Bay 1-23	23	BB 49	49
	Bass&Flinders-Hacking Pt	Port Hacking 1-8	8	PH 10	10
PC:NSW02.03	*C. Three Pts-Pt Hacking*	*NSW 290-340*	*155*	*800-926*	*288*
NSW02.04.01	Hacking Pt-Bellambi Pt	341-367	27	926-974	48
NSW02.04.02	Bellambi Pt-Red Pt	368-378	11	974-992	18
NSW02.04.03	Red Pt-Bass Pt	379-385	7	992-1010	18
NSW02.04.04	Bass Pt-Black Hd	386-399S	14	1010-1044	34
NSW02.04.05	Black Hd-Beecroft Pt	400-408	9	1044-1084	40
PC:NSW02.04	*Pt Hacking-Beecroft Pens.*	*NSW 341-408*	*68*	*936-1084*	*158*
NSW02.05.01	Beecroft Hd-Pt Perp.	0	0	1084-1093	9
NSW02.05.02	Pt Perpendicular-Bowen Is	409-438	30	1093-1146	53
NSW02.05.03	Bowen Is-St Georges Hd	439	1	1146-1159	13
NSW02.05.04	St George Hd-Red Hd	440-460	21	1159-1185	27
NSW02.05.05	Red Hd-Warden Hd	461-471	11	1185-1203	17
NSW02.05.06	Warden Hd_Wasp Hd	472-514	43	1203-1264	61
PC:NSW02.05	*Beecroft Hd-Wasp Hd*	*NSW 409-514*	*106*	*1084-1264*	*180*
NSW02.06.01	Wasp Hd-Three Islet Pt	515-522	8	1264-1276	12
NSW02.06.02	Three Islet Pt-Mosquito Pt	523-540	18	1276-1302	26
NSW02.06.03	Mosquito Pt-Bingie B. Pt	541-577	37	1302-1346	44
NSW02.06.04	Bingie B. Pt-Mystery Bay	578-611	34	1346-1383	37
NSW02.06.05	Mystery Bay-Goalen Hd	612-637	26	1383-1418	35
NSW02.06.06	Goalen Hd-Tathra Hd	638-659	22	1418-1444	26
NSW02.06.07	Tathra Hd-Worang Pt	660-678	19	1444-1497	53
NSW02.06.08	Worang Pt-Red Rock	679-703	25	1497-1521	24
NSW02.06.09	Red Rock-Green C	704-709	6	1521-1548	27
NSW02.06.10	Green C-Jane Spiers	710-713	4	1548-1570	22
NSW02.06.11	Jane Spiers-C Howe	714-721	8	1570-1592	22
PC:NSW02.06	*Wasp Hd-C Howe*	*NSW 515-721*	*207*	*1264-1592*	*328*
	Region total		*521*		*1032*
	NSW Open coast	*NSW 1-721*	*721*		*1592*
	NSW Bays	*Bay beaches*	*120*		*187*
	NSW total (open & bays)		*841*		*1779*

[1] NSW beach number and km distance from QLD-NSW border